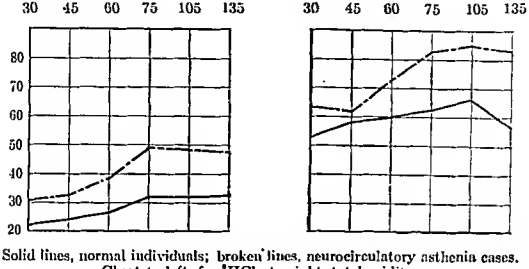
figures for the preceding period and the last period being 28.7, 31.4 and 32.6 respectively.



Solid lines, normal individuals; broken lines, neurocirculatory asthenia cases. Chart to left, free HCl; to right, total acidity.

Conclusion. In patients suffering with neurocirculatory asthenia there is a very definite increase in the total acidity and free hydrochloric acid as compared with controls. These figures do not represent abnormal hyperacidity. As Rehfuss[5] has shown that the usual conception of hyperacidity is erroneous, an apparently normal acidity of over 100 is common. They do show, however, that almost uniformly soldiers suffering with neurocirculatory asthenia as contrasted with apparently normal soldiers, both eating the same food, under identical routine and under the same conditions of living, show a higher gastric acidity. This is a diagnostic point which may be of value in differentiating the disorder in questionable cases. It surely seems to add further evidence to that already accumulated that these soldiers are suffering from a neurosis with which is probably associated a hyperirritable vagus.

NEWER CONCEPTIONS OF THE PATHOGENESIS AND TREATMENT OF EMPYEMA.*

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Empyema is one of the oldest diagnosticable diseases. It was known even to Hippocrates. It cannot be said, however, that its study and treatment have received the precision and refinement

[5] Possibilities of Fractional Gastric Analysis, Jour. Am. Med. Assn., 1918, lxxi, 1534.

* The Mütter Lecture read before the College of Physicians of Philadelphia, December 12, 1919.

that we would expect from its antiquity. For years the only facts worth knowing about empyema was that it followed pneumonia and that its treatment consisted in that simple formula, "incision and drainage." There was nothing obscure. The pathology and diagnosis were simple, the operation even more simple, so that for decades empyema seemed to offer no opportunity for more intensive investigation. It was more or less a closed subject. Here and there, it is true, an article appeared on empyema, but these concerned themselves mainly with technical modifications of drainage. This state of affairs bred a sense of satisfaction among surgeons in regard to the results of their treatment. The results seemed good enough, and if the results were not better, it was not the fault of the surgeon but of the disease. I confess that I, too, was one of that number, and felt that the mortality was as low as it could possibly be. I remained in this state of exaltation until the year 1914, when at my instigation my adjunct, Dr. A. O. Wilensky,[1] investigated the mortality of empyema at Mount Sinai Hospital for the preceding ten years. To my chagrin and humiliation he found that the mortality reached the formidable figures of 28 per cent. (In partial justification of these figures I may say, in passing, that this mortality includes both adults and infants; of the total of 82 deaths, 53 occurred in infants below three years of age.) This mortality was much higher than my uncorrected sense of values had afforded me and was a rude shock to my complacency. Now this high mortality, I am proud to say, is not distinctive of Mount Sinai Hospital; it is certainly no larger, and in many instances even smaller, than at other hospitals; nor are there any reasons why it should be; the operation and method of treatment was the conventional or standard one practised at every hospital in the country. I therefore suddenly acquired a respect for the disease that I had never felt before, for there are not many operations in surgery that give a mortality of 28 per cent., especially one so commonly performed. I made up my mind then and there that a disease of such formidable mortality demanded investigation, and that is why I welcomed my appointment as one of the surgical members of the Empyema Commission. The conditions under which the commission made their investigations were ideal.

Not only was the attack ably directed from every viewpoint, clinical, bacteriological, pathological, roentgenological, etc., but, and this is important, we were able for the first time to intensively study the disease not only *en masse*, but to witness it, what is so unusual for the surgeon in civil life, from its very inception. As a result of my military experience upon the Empyema Commission at Base Hospital, Camp Lee, General Hospital No. 12, Biltmore, N. C., as chief of the surgical service at Camp McClellan, and later as consultant in the Surgeon-General's Office, my views upon the

pathogenesis and treatment have profoundly altered from those I held while practising civil surgery, and these it is now my privilege to submit to you.

PATHOLOGY AND PATHOGENESIS.

A knowledge of the pathology and pathogenesis of empyema is of fundamental importance in order to understand the principles underlying its treatment. An extensive operative and autopsy experience has helped me to clarify my notions of the pathology of empyema considerably, and has profoundly modified my views concerning the treatment. I shall not enter at great length into the hitherto accepted views concerning the pathogenesis of empyema, except to say that the common understanding hitherto has been that the pleura became infected by contiguity from the inflamed lung. This view did not appeal to me for two reasons: My first objection is that this mode of infection does not occur in any of the other closed serous cavities of the body. Take the peritoneum for instance and its most frequent source of infection, the appendix. Every surgeon with any experience knows that a diffuse peritonitis rarely if ever occurs unless there has been a perforation of this organ, or the walls are so necrosed as to permit of easy transmission of bacteria into the peritoneal cavity. This is likewise true of the hollow viscera of the abdomen. Reasoning by analogy, therefore, it is difficult to see why the pathogenesis of infection of one serous membrane should be different from that of another. My second objection is that infection of the pleura by contiguity would presuppose a direction of the lymph current opposed to that demonstrated and accepted by physiologists and anatomists. To obviate this a double set of lymphatics has been assumed, one passing from the hilum to the pleura, the other passing in the reverse direction. This contention, however, is only a hypothesis and not a fact.

It has seemed to me, therefore, that upon theoretical grounds alone a different pathogenesis than that of contiguity was necessary to explain purulent infections of the pleura, and it has appeared to me to be very probable that gross contaminations of the pleura should occur from a focus in the lung, just as similar infections of the peritoneum occurred. On the constant lookout for such findings, I was not at all surprised, many years ago, to see at autopsy an empyema that had resulted from a rupture of a small subpleural pulmonary abscess. I wondered whether this was not the common rather than the exceptional cause. As operation does not permit of sufficient exposure the demonstration of such a pathogenesis requires autopsy material. This became available *en masse* at Camp Lee, in the spring of 1918, and in a series of perhaps three dozen autopsies we were able to demonstrate in

a great many instances one or more subpleural abscesses, some of which had perforated into the pleura. Additional corroborations of this pathogenesis was furnished by the influenza epidemic at Camp McClellan during my incumbency as chief of the surgical service. Lieut.-Col. E. K. Dunham, who was associated with me on the Empyema Commission, again demonstrated a perforated subpleural abscess in every case of empyema that came to autopsy.

The localization of the empyema depends entirely upon the situation of the ruptured subpleural abscess. If, as is most frequently the case, the empyema is a general or diffuse one the abscess is usually located upon the convex surface of the lung. If the abscess is located in a fissure an interlobar empyema results. When the abscess is on the mesial aspect of the lung we will find retrosternal pus pockets between the lung and the mediastinal pleura. The latter were more common in the earlier streptococcus epidemic than in the later influenza epidemic.

An additional and perhaps obvious proof that ruptured subpleural pulmonary abscesses occur in empyema is the frequent experience that irrigation of empyema cavities with irritating solutions, such as Dakin's solution, results in coughing and choking, showing that communications exist with a bronchus. This perhaps explains why in former years irrigations of empyema cavities with even bland solutions were considered unfeasible. Such communications are furthermore very often demonstrable by bismuth roentgen-ray examinations. I believe these communications exist in every empyema; if small, they heal promptly; if large, they may be the cause of considerable difficulty during the treatment.

I need hardly dilate upon the fact that smaller and larger abscesses occur not only beneath the pleura but also well within the parenchyma of the lung in pneumonias, especially in those of the streptococcic variety. If small they may be absorbed; others rupture into a bronchus; if the infection becomes attenuated they become remediable by operation; usually, particularly if they are multiple, they cause a fatal sepsis. The subpleural varieties offer perhaps the most favorable prognosis, because at worst they form an empyema by rupturing into the pleural cavity. When they do the rapid development of an empyema is, I believe, favored by the presence of the small amount of serous fluid in the pleural cavity, which is present in every case of diffuse pneumonia.

The analogy between infections of the pleura and of the peritoneum is therefore remarkably complete. Unruptured infections within the abdomen also cause serous exudates, which, if uninfected, become absorbed. The one important physiological difference between infections of the pleura and peritoneum is the greater and constant mobility of the lung as compared to the sluggish peristalsis of the intestine, so that adhesions are less liable to form; a free serous pleurisy is therefore the rule.

When now the serous pleurisy is converted into a seropurulent or purulent exudate, encapsulation occurs just as in the peritoneum and is due to a deposit of fibrin on the periphery. The encapsulation also, as in the peritoneum, may be diffuse, localized or multiple. Owing to the recumbent posture the fluid usually collects in the supradiaphragmatic and posterior portions of the thorax, giving rise to the most common form of empyema. Isolated and localized forms, however, are frequent findings and multiple encapsulations are not uncommon.

The important point to remember, especially in reference to treatment, is that, whereas a serous or seropurulent pleurisy is always free, a purulent pleurisy is nearly always encapsulated. The encapsulation may enclose an extensive area, almost the entire pleural cavity, but at some time or another adhesions between the parietal and visceral pleura are nearly always found. An absolutely free empyema, occupying the entire pleural cavity, is, in adults at all events, rarely found.

TREATMENT.

Primarily I wish to emphasize that an empyema in the stage in which frank pus is obtained by aspiration is already an end-product, the terminal event of an infectious process in which the first stage is a pneumonia with a small serous pleurisy, and the second stage a pneumonia with a greater exudation of seropurulent material. The treatment of empyema really begins in the latter stage, so that in this disease, as well as in all acute surgical infections, an early diagnosis is of prime importance. Speaking again in terms of analogy it would be equally as logical to begin the treatment of appendicitis only when an abscess has formed as to initiate the treatment of an empyema only when the exudate has become manifestly purulent. It was not merely the observation of empyemata *en masse*, but the opportunity to witness the development of an empyema from its very incipiency that made my military experience in this disease of so much value to me.

I have therefore divided the subject of the treatment of empyema into three stages:

I. The formative stage.
II. The acute stage.
III. The chronic stage.

I. The Formative Stage.

The formative stage of a case of empyema is one of the most interesting phases of the problem. The exact period of its onset can often not be told with precision, because, as already pointed out, every case of pneumonia is accompanied by a certain amount

of serous effusion. As long as the amount is within small limits it does not deserve much attention; in fact, there is very little doubt in my mind that small effusions of a serous nature are usually overlooked.

Furthermore, it also appears to me that early effusions may properly be subdivided into two periods. The first period is merely an evidence of the inflammatory process in the lung and in the greatest majority of instances is moderate in amount. The second period begins with the rupture of the small subpleural pulmonary abscess, which is followed by an intense inflammation of the pleural surfaces and an infection of the fluid, with a very rapid increase in its amount. I have also gained the impression that the amount of the exudate and the rapidity of its accumulation depends to a large extent upon the nature of the infecting organism. Thus I believe, for instance, that the exudates caused by the hemolytic streptococcus, as was seen in the 1917–1918 epidemic, were exceedingly rapid, not only in their formation, but also in their accumulation. I have seen cases of thirty-six to forty-eight hours' duration in which one pleural cavity was filled, and in which reaccumulation was occasionally so rapid that aspiration had to be repeated at twelve-hour intervals. On the other hand the empyemata which followed the later influenza epidemic were slower, both in their formation and reaccumulation.

The patient at this stage is suffering from a number of things, all of which demand appropriate treatment.

1. Of foremost importance is the toxemia, caused by the pulmonary infection, and to a slight degree also by the infected exudate in the pleura. This requires the usual treatment appropriate to the case. In general terms it is what is called "supportive." If successful it serves to tide the patient over the most important phase of the illness.

2. The pneumonia which at this stage of the illness is still in a florid state demands careful attention and appropriate treatment.

3. The large amount of exudate brings in its train a tremendous loss of nitrogen. This observation and its therapeutic importance has been made the subject of an exhaustive study by Captain Richard Bell, of the Empyema Commission.[2] To replace this loss the patient must be fed on a diet of a high calorie value. Clinical observations have corroborated the great importance of this measure.

4. Of equal importance with the preceding is the presence of the exudate in the pleura. I have purposely avoided the words "infected" exudate because I look upon the mechanical presence of the fluid as of greater importance even than the infection. There can be no excuse whatsoever for overlooking it; particularly in adults, the physical signs of the same are so characteristic that even in the absence of roentgen ray and other instruments of precision it should always be readily diagnosticated.

Primarily the patient is suffering from its mechanical presence and this exerts its deleterious effects: (1) By compression of the affected lung (by some this influence is considered beneficial); (2) by pressure upon the mediastinum and compression of the healthy lung; (3) and most of all by pressure upon the heart and consequent kinking of the great vessels. It is for this reason that left-sided exudates are borne less well than those on the right.

To relieve these mechanical effects of large exudates we resorted to the simple device of aspiration with an apparatus that does not permit the entrance of air.

It was truly remarkable to witness the almost immediate benefits of this measure. The patients were more comfortable, the dyspnea was less, the cyanosis was not so marked and the pulse improved in quality. Aspiration was repeated as often as the fluid reaccumulated in sufficient amounts as to demand it; in some instances, especially in the streptococcic form as often as every twelve hours. In a few instances aspirations were even curative.

The question may now be asked why was not an early thoracotomy done? On theoretical grounds such an operation might obviate both the mechanical and toxic effects of the exudate. Practically, however, an early thoracotomy is absolutely contraindicated, and for the following reasons:

I shall elucidate my argument by first describing the pathogenesis of pleural exudates.

A vertical section of one-half of the normal thorax may be represented as in Fig. 1. As is seen the lung entirely fills the pleural cavity; the parietal and visceral pleuræ are in contact, being separated merely by a very thin layer of fluid.

If an exudate or transudate forms the fluid, being heavier than the air-containing lung, collects in the dependent portions of the pleura and crowds the lung upward and toward the vertebral gutter. This is represented diagrammatically in Fig. 2. This is what usually happens in pleurisy with effusions, in pleural transudates from cardiac or kidney disease, etc.

Suppose now that a subpleural pulmonary abscess ruptures and an early empyema develops. There is a sudden increase in the amount of exudate and a corresponding aggravation of the symptoms.

If a thoracotomy is now performed the fluid suddenly escapes and there is an equally sudden inrush of air, followed by an immediate collapse of the lung. This is illustrated in Fig. 3. The occurrence just related is immediately followed by a fluttering of the as yet uninfiltrated mediastinum, impairing still further the action of the heart. Finally, if the patient survives, the mediastinum becomes fixed with the convexity toward the unaffected side. This condition is represented diagrammatically in Fig. 4. (In parentheses I merely wish to mention that these observations upon pneumothorax apply only to large thoracotomies, and not

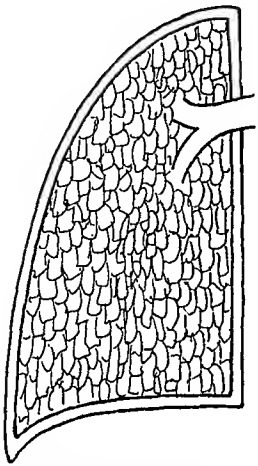

FIG. 1.—Vertical section of one-half of the normal thorax.

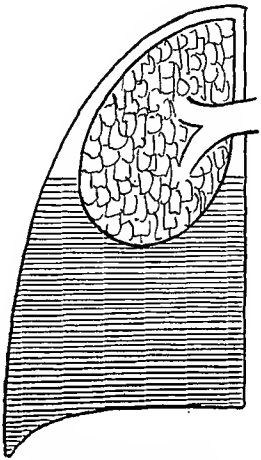

FIG. 2.—Free exudate into pleural cavity.

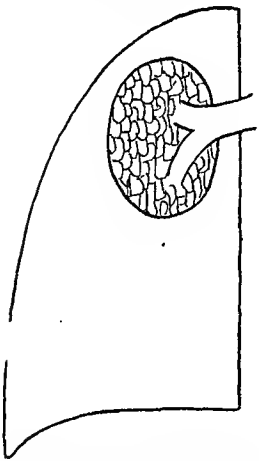

FIG. 3.—Collapse of the lung caused by thoracotomy in the presence of a free pleural exudate.

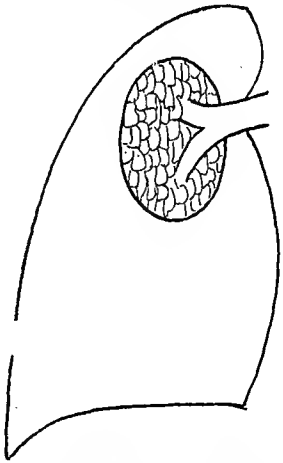

FIG. 4.—Collapse of the lung and fixation of mediastinum toward opposite side caused by thoracotomy in the presence of a free pleural exudate.

to instances in which the opening is of smaller size than the chink of the glottis.) The pathological physiology of pneumothorax has been ably investigated by Garre and Quincke, and by Graham and Bell, of the Empyema Commission.

Theory aside, however, early thoracotomies are attended by a terrible mortality, as the statistics in our military camps during the epidemic of 1917 and 1918 woefully testified. Early operations were probably prompted by the enthusiasm of both internists and surgeons, who for the first time saw empyemata in large numbers develop under their very eye, and felt that early operations, which in other suppurative surgical affections is a great desideratum, would give similarly brilliant results. It was only when frightened by the formidable mortality and a halt was called on early operations that the statistics improved. The patients died not only in large numbers but promptly after the operation. When we consider that these operations were done upon a patient who was at the same time sick unto death with an active pneumonia it is not surprising that the mortality was as large as it is.

Another but less important contra-indication to early operation is the fact that even if the patient survives, the lung becomes fixed in its collapsed position by adhesions, so that a huge empyema cavity results, which takes an interminable time to heal.

To sum up, the treatment of empyema in the formative stage resolves itself to the formula *nil nocere*. The only surgical procedure indicated is frequent aspiration of the chest.

II. Treatment of the Acute Stage.

When the seropurulent fluid changes into pus, adhesions form between the opposing surfaces of the pleura. A cross-section of the chest in such a condition is represented in Fig. 5. These adhesions are important because they anchor the lung to the parietes. The thorax, therefore, can now be opened without causing complete collapse of the lung. A cross-section of the thorax after opening is represented in Fig. 6. I am speaking now only of the commonest forms of empyema, namely, those situated in the supradiaphragmatic and posterior portion of the chest. Slight variations obviously occur in empyemata in other situations, but the underlying principles remain the same.

I do not know just when these adhesions form; the important point is that I have practically always found them when the chest contains frank pus; so that, I repeat, nearly every empyema is an encapsulated one.

Furthermore, the patient at this time is in a much improved general condition; the pneumonia is over and the general toxemia has subsided. We have nothing to contend against now but the empyema, which causes symptoms from absorption of toxic material

FIG. 5.—Empyema of chest, note adhesions between the visceral and parietal pleura upon the periphery of the oxudate.

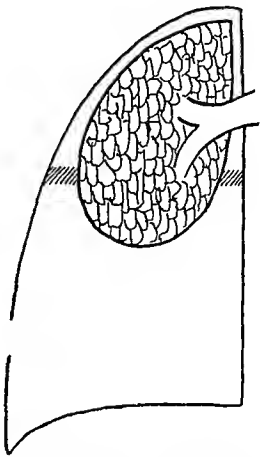

FIG. 6.—Empyema of the chest after thoracotomy; note absence of collapse of lung.

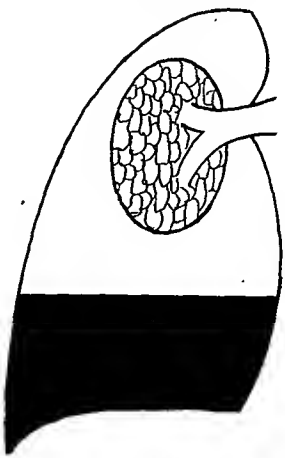

FIG. 7.—Acute pyopneumothorax.

and from the mechanical effects of the fluid alone. The dangers from absorption have, I believe, been hitherto greatly exaggerated, and while I do not advocate needless delay in performing a thoracotomy the necessity for this operation is by no means urgent. Indeed, the only indication for urgent or early thoracotomy is in those exceptional cases in which a pulmonary abscess, directly in communication with a large bronchus, ruptures into the pleura. There is thus formed an acute hydropneumothorax or pyopneumothorax under extreme tension, due to the continuous escape of air into the pleural cavity. The condition is diagrammatically represented in Fig. 7. These patients suffer intensely from dyspnea, and as the lung is already collapsed no harm can be done by an early thoracotomy in order to afford relief.

The operation in the acute stage is one of the safest known. This safety, as already pointed out, is based upon the fact that all around the periphery of the fluid, no matter how large or how small, there is a pyogenic membrane of sufficient firmness to encapsulate it and to convert it into a simple intrapleural abscess. The appropriate treatment is, therefore, that of every abscess, namely, incision and drainage.

In spite of its simplicity each step of the operation requires the greatest punctiliousness. I shall begin with a description of the operation in the commonest form of empyema, namely, that which is located in the supradiaphragmatic and posterior portions of the pleura.

1. Anesthesia. All operations on adults and, for that matter, also on older children, can and should be carried out in local anesthesia. The anesthetic of choice is novocain in 1 per cent. solution. The line of the incision is first injected endodermatically, and from this area the deeper tissues are thoroughly infiltrated. It is important to remember that sufficient time should be permitted to elapse to obtain the full effect of the anesthetic. Many a complete failure is due to the neglect of this primary rule; and once the confidence of the patient is lost by failing to obtain the promised analgesia the subsequent steps cannot be properly carried out. I never employ a general anesthetic, and doubt that it is ever indicated, if only care, gentleness and patience are exercised.

2. Simple Intercostal Thoracotomy versus Costatectomy. Personally I prefer and advocate in all primary operations for empyema a simple intercostal incision. If critically analyzed the object of the entire operation is to make a liberal incision into the pleura and to insert large enough drainage tubes. I maintain that this object can be obtained fully as well by an incision through an intercostal space as through a retrocostal space obtained by rib resection. I am sure I use tubes as large (to be exact, 40 F.) as the advocates of costatectomy; very often I use even two or more tubes. The advocates of costatectomy claim that the tubes are

kinked unless this is done, but in a great many operations I have never seen such an occurrence and doubt that it can occur.

Costatectomy has the additional disadvantage that in spite of the greatest care the ends of the divided rib very frequently become necrotic and thus become the source of continued suppuration.

Costatectomy, however, is such an ancient and time-honored operation that it is here to stay. I do not deprecate its use; let those who wish it continue to do so. I hold, however, that it is unnecessary.

3. THE SUPERFICIAL INCISION. (*a*) *The Site of the Incision.* In general the site of the incision depends upon the location of the empyema as guided by the physical and roentgen-ray examination. The incision must fulfil two purposes: (1) It must afford adequate drainage and (2) it must permit appropriate medication of the cavity. The drainage must be free and unobstructed both in the recumbent and erect posture. In the most common location of empyemata, *i. e.*, those which occupy the lower part of the thorax, I prefer an incision in the eighth intercostal space, just behind the posterior axillary line, or at the midscapular line. Theoretical objection might be raised to this location by the fact that the ascent of the diaphragm which occurs in the course of healing of every empyema might cause a kinking of the drainage-tube, but in practice I have never found it to occur.

(*b*) *The Incision of the Extrapleural Soft Parts.* The cutaneous incision should be of ample length. Two to four inches, depending upon the amount of adipose tissue present; so that with proper retraction all subsequent steps can be carried out under the guidance of the eye. It is important to remember that the incision, if made, as is usually the case, with the arm hyperabducted, will shift when the dependent position of the arm is restored. If this is not considered the surgeon will find that his cutaneous incision is not in alignment with the pleural incision. This is a circumstance which is extremely annoying in the after-treatment, and may require a second incision at right angles to the first. It is readily obviated by outlining the incision while the arm is in the adducted position.

Usually I also excise some of the intercostal muscles. This step has a twofold object: (1) It exposes cleanly the underlying endothoracic fascia and parietal pleura and (2) because the shreds of divided muscle have a tendency to close up the wound and are a hindrance in the after-treatment.

4. THE INCISION OF THE PLEURA. With proper retraction there is now exposed in the bottom of the wound the endothoracic fascia the deep layer of which is lined by the parietal pleura. Both these structures are very sensitive and may be anesthetized additionally by the direct injection of novocain. A small incision is made first and the pus is slowly evacuated; subsequently the incision into the pleura is extended to the full length.

5. Drainage Material. I use as direct postoperative drainage material a single large sized rubber tube of a rather stiff quality and about one foot long. The tube is forced through a tiny perforation in a piece of rubber dam, approximately four inches square, which is fixed to the tube with a thread at a distance from $2\frac{1}{2}$ to 4 inches from its thoracic end, depending upon the thickness of the chest wall. Near the thoracic end a large fenestra is cut into the tube, so that the fenestra is just inside the pleural cavity (Fig. 8). This must be gauged with some care, in order to permit the rubber dam to be flush with the skin. No sutures are ever employed; on the contrary, both the pleural and external incisions are packed

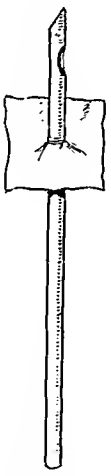

Fig. 8.—Drainage-tube for empyema.

wide open with gauze. The rubber dam is laid smoothly on the skin and its edges are firmly fastened to it by overlapping broad strips of adhesive plaster. A small dressing and a firm binder are applied in such a manner that the long end of the tube (temporarily clamped) finds free egress.

I do not irrigate the cavity upon the operating table, but, as will be seen, I do so promptly upon the return of the patient to his bed. I do not do so from any fear of the irrigation, but merely as a matter of convenience and in order not to prolong the operation unduly.

This matter of irrigation of an empyemic cavity is a very impor-

tant point and deserves careful consideration, as the entire modern treatment of empyema depends upon our ability to do so. If there is anything definitely settled in surgery it is that no empyema should ever be irrigated. There is apparently no valid reason for this strenuous interdiction; as a general rule explanations are given which, if critically examined, will be found not to explain at all. Personally I believe there is a fairly good reason for it, which, however, has not been recognized until now, namely, the frequently found communications between the pleural cavity and the bronchial tree. As already stated, purely for reasons of convenience, I do not irrigate the pleural cavity upon the operating table, but I do so promptly, almost immediately, upon the return of the patient to his bed.

It is greatly to be regretted that even the advocates of the Carrel-Dakin treatment frequently state that certain cases of empyema cannot be treated with Dakin's solution, because it causes an intensely irritating cough; on the other hand the opponents of the method are only too prone to sneeringly discard the entire treatment. As a matter of fact it is not at all necessary, because this irritating cough occurs only when there is a very large open bronchus communicating with the pleura and when the cavity is overdistended with the solution. Experience has taught me that all these patients will tolerate Dakinization perfectly well if administered in the following manner: I usually begin with very small quantities of solution, say 5 c.c. into each tube, and gradually and slowly increase the daily amounts. Under such treatment the pleuropulmonary opening closes in time, and more than that, patients become accustomed to Dakin's solution, until finally they tolerate instillations of full doses.

Upon reaching the ward a simple combination instillation and suction apparatus is attached to the free end of the drainage-tube by means of a T-tube; at a convenient point a second attachment is made for a bottle to receive the discharges (a mixture of pus and Dakin's solution) from the empyema cavity (Fig. 9).

Once an hour, or more or less frequently as indicated, the siphon part of the apparatus is discontinued by clamping; at the same time the instilling apparatus, an ordinary Dakin container, is opened and the requisite amount of Dakin's solution is allowed to run in. After the lapse of five minutes the suction apparatus is reopened and the solution plus secretions is siphoned out. The suction is continued until the next period of instillation.

The advantages of this combination apparatus, consisting of a drainage-tube, which fits air-tight to the chest (in fact is part of the chest wall), instillation apparatus, suction apparatus and receiving bottle are the following:

1. All the discharges are collected into the receiving bottle, and in consequence the wound does not require any change of dressing.

I usually postpone the dressing for eight to ten days, which is as long as the patient is connected with the apparatus.

2. If the operation has been properly carried out the cavity is perfectly dry, and there being no retention of pus, fever does not arise.

3. An early opportunity is given to permit a prompt and efficient use of Dakin's solution.

4. The vacuum created adds to a limited extent in the expansion of the lung. I confess, however, that I do not lay much stress upon the last point.

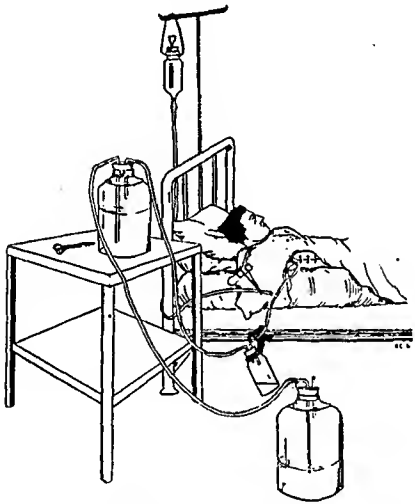

FIG. 9.—Instillation and suction apparatus.

It is far from me to urge the use of this suction apparatus and I do not consider it in any manner essential. If there be some who do not care to take the trouble with it, or if the hospital personnel be insufficient to devote the necessary time to supervise it, it need not be used. Under such circumstances I would advise the introduction of two drainage-tubes and to pack the wound. Such patients will require an earlier change of dressing.

As is seen the advantages gained from the suction apparatus, as used by me, are not of a fundamental nature. I make this statement with a certain amount of hesitation, because entire systems of treatment have been built up around the principle of a vacuum created by means of suction apparatus. The method originated

as far back as 1891 and was introduced by Bülau under the name of "Heberdrainage," but was subsequently abandoned. It was revised and numerously modified in conjunction with Dakin's solution in various army hospitals. *A priori* these methods are very fascinating; regrettably the results, as far as permanency is concerned, are not particularly brilliant.

AFTER-TREATMENT. All patients are dressed only once in twenty-four hours. All the old dressings, including the Carrel tubes and "safety valves" (to be subsequently described) are removed and are replaced by fresh ones. All rules as enunciated by Carrel for the preservation of a perfect asepsis are rigidly adhered to.

The skin for a liberal area around the wound is cleansed, first with a dry cotton sponge, and subsequently with a cotton sponge dipped into benzine. A soft-rubber catheter (25 to 30 F.) is introduced into the cavity, and is connected with a Dakin container. The cavity is thoroughly flushed with Dakin's solution, the patient being turned from the lateral to the prone position, and *vice versa*, until the return flow is perfectly clear.

From one to four Carrel tubes, depending upon the size of the cavity, are now introduced into the cavity; it is the aim to introduce them into various portions of the cavity, though, being done more or less blindly, this is often illusory. In very long and very irregular cavities I have occasionally made use of tubes which were armed with a silver wire stylet. A short drainage-tube, about the thickness of a lead pencil, with one fenestra, guarded by a safety pin, so-called "safety valve," is finally introduced, to permit a free escape of Dakin's solution and secretions.

Right here I might digress for a moment in order to mention that the *rationale* of the entire postoperative treatment must be thoroughly understood. One must not fall into the error of thinking there is something supernatural in Dakin's solution, so far as the cure of an empyema is concerned. All that it can do, or is expected to do, is to sterilize the cavity. It can never supplant good surgery, and the best surgical principle in the treatment of an empyema is good surgery. This is self-evident, and yet I have seen this fundamental principle violated only too often. I have seen innumerable instances in which a single Carrel tube was introduced into the cavity and then Dakin's solution was poured into it; the patients were septic; the withdrawal of the tube was followed literally by the escape of quarts of pus.

I trust it is not necessary for me to reiterate that one of the fundamental prerequisites in the use of Dakin's solution is a good and properly prepared solution; and yet I have seen this rule also frequently violated. As a matter of fact I have found there is no short cut in the Carrel-Dakin treatment, and it is best to follow all directions to their minutest detail. I would go so far as to say, if results are not obtained, it is not the fault of the method but of a faulty application.

The vicinity of the wound is protected, as usually, by sterile vaselin gauze strips. At a distance from the wound the skin is protected from the irritating action of Dakin's solution by the application of Lassar's paste, which was found to be rather more efficacious in this respect than vaselin. As a general rule it may be stated that it is infinitely easier to prevent than to treat Dakin's burns, and it can be very readily done by slight care.

The wound is packed with small gauze sponges moistened with Dakin's solution. A few small fluffs of dry, sterile gauze are placed next to the wound and over that a liberal pad made up of either reclaimed gauze or cotton, which is held in place by a firm binder. The binder should be applied snugly and be provided with shoulder-straps. Nothing is more annoying than a shiftlessly applied binder, as it permits the displacement and loss of tubes and is a source of constant trouble. The Carrel tubes emerge on top of the binder, usually in the vicinity of the shoulder, where they can be readily reached for subsequent instillations.

Definite instructions are given for the instillation of the requisite amount of Dakin's solution; the quantity depends upon the size of the cavity and varies from 25 c.c. to 100 c.c.—in general about one-half of the volume of the cavity—too much cannot be used. It is distributed in equal amounts through all the tubes. Directions also are given as to the intervals between instillations. I have found hourly instillations during the daytime to be most satisfactory; at night the time interval is two hours.

The dressing is not touched for twenty-four hours. It is true the large quantities of Dakin's solution used saturate the dressings pretty thoroughly; but some of it escapes by evaporation, and upon inquiry I did not find that the patients complained of this seemingly annoying drawback.

It is very remarkable, but already at the first dressing the discharge has lost its frankly purulent character. If the case has been properly operated upon, and in the most dependent part of the cavity, the cavity will be found to be perfectly dry, as all the discharges escape through the safety valve. In order to obtain the maximum benefit from the solution, the instillations are given in the recumbent posture with the drainage opening uppermost; even ambulatory patients are ordered to remain in this position for five minutes after each instillation. Exception to the recumbent position is made in cases complicated by large pleuropulmonary fistulæ, as in this position the injected fluid may find its way too readily through the fistula into a bronchus. In almost every one of these patients a position will be found, either prone, or sitting upright, or front, or back, or upon the right or left side in which the instillations are well borne.

It is almost marvelous to see the effect of a properly carried-out treatment. All pus and odor disappear as if by magic. I have

literally dressed one hundred patients, and in all the patients combined not half a teaspoonful of pus was found; in fact, in some cases it was difficult to obtain enough secretions to make a proper culture.

In some of the cases of long standing, *i. e.*, those which have been neglected and in which there was for a long time imperfect drainage, we had an opportunity to watch the character of the discharge. Its consistency was not unlike that of uncooked white of egg, in which there were enmeshed a few grayish particles. With progressive sterilization the discharge lost this appearance and the irrigation was followed by small hemorrhages. We interpreted the first finding as due to the liquefying action of the Dakin solution upon the dense, fibrous deposit upon the pleura, and the subsequent hemorrhages as due to the irritation of pleural granulations.

These slight hemorrhages, which are of no consequence whatsoever, must not be confounded with those occasionally occurring recurrent large hemorrhages, which may be so large as to endanger life. They have been ascribed to the effects of Dakin's solution; as a matter of fact, these accidents have been brought forward as a very powerful argument against the use of Dakin's solution. I am firmly convinced that this is an error. I also have proof that these large hemorrhages are due to an erosion of the intercostal artery, which is caused by the pressure of the drainage tubes. In the slighter cases a firmly applied tamponade may be sufficient to arrest the hemorrhage; in the more severe and in recurrent cases it may become necessary to ligate the vessel.

It is most interesting to follow in cases recently operated upon the changes caused by Dakin's solution upon the infected pleura. When an empyema is operated upon the pleura is found coated throughout by a soft, grayish deposit of varying thickness, composed of fibrin and pus, holding enmeshed myriads of bacteria. As sterilization proceeds this coating disappears very rapidly, exposing a smooth, glistening surface; particularly upon the pulmonary surfaces it is so thin that the underlying lung workings become readily visible and recognizable.

Twice a week smears and cultures are made from the cavity. When very low counts are obtained these are made daily. I place much more reliance upon the cultures than upon the smears; in the latter it is occasionally difficult to differentiate between a bacterium and nuclear debris. As a general rule it may be stated that for every bacterium seen upon a slide about 200 colonies will develop upon a poured plate. When laboratory facilities are not obtainable the counting of bacteria upon a slide may be substituted, however, only with the reservation above mentioned. When sterility is reached the treatment is continued arbitrarily for another week or ten days; at the end of that period all tubes are

left out; in fact, all treatment is discontinued; merely an occlusive dressing is applied. Prompt and permanent healing is the result in many instances, in one case in as short a period as thirteen days. The average time of healing, barring the exceptionally low and exceptionally high periods, which really belong to the chronic stage, is about four weeks.

I have attempted in some cases a plastic closure of the drainage opening, as recommended by the Rockefeller Institute. But the results obtained did not warrant me in continuing this practice. Moreover, I do not see any particular indication for doing so. If the cavity is not sterile a premature closure of the wound is sure to be followed by an infection, with subsequent breaking down of the suture line; if, on the other hand, it is sterile, the wound closes so promptly that even the trivial operation of refreshing and suturing the edges is uncalled for.

Considerable importance is ascribed by most surgeons to the use of blowing bottles in order to encourage the lung to expand. I will not deny that this device helps to a limited degree, but I have also found that most patients, after the enthusiasm of a new toy has worn off, discontinue their use. I have found more benefit from properly carried out light exercises. I encourage particularly light work around the wards, which keeps the patient interested and amused. These exercises are of particular benefit to the myocardium, which, because of the primary toxemia, is always in a debilitated condition.

Patients are encouraged to leave the bed very promptly after the operation. Those that are connected to a siphonage apparatus leave their bed upon the day that the apparatus is discontinued; those that have simple drainage even earlier.

In an earlier part of my paper I have already emphasized the importance of keeping up the nutrition of the patients.

EXCEPTIONAL OPERATIONS.

The operation as just described is applicable particularly in the commonest form of empyema, namely, that the boundaries of which may, roughly speaking, be stated as mesially the lung, laterally the chest wall and inferiorly the diaphragm. An empyema may, however, occur in exceptional locations; as a matter of fact there is no part of the pleural cavity which is immune. The diagnosis of these exceptionally located empyemata, particularly in those of small size, is beset with difficulties. That these exceptionally located empyemata must be operated upon at the place of their location is self-evident; occasionally weird incisions in weird locations must be used. Particularly difficult regions are those in the upper part of the thorax behind the pectoralis major; in these cases I have found it preferable to make a vertical incision,

and to divide the fibers in a transverse direction to the necessary extent. If the muscle is simply retracted it is very probable, that at the termination of the operation the muscle will cover up the drainage opening; a most annoying complication in the after-treatment. I have never seen any drawback from the partial division of the pectoralis major.

Empyemata situated directly in front of the scapula are best reached from the axilla.

Interlobar empyemata are not only difficult to diagnosticate but also difficult to operate. Their diagnosis requires a very careful examination, a knowledge of anatomy and demands particularly a very careful roentgenray study. I am of the opinion that, unless the symptoms are extremely urgent (and, as a rule, they are not), these cases should not be operated upon in haste. A careful differentiation should be made between cases in which the general pleura plus the interlobar pleura is infected and cases in which only the interlobar space is involved. In the former the operation is of no danger; in the latter, particularly if only a small amount of pus is present, and there are no adhesions between the parietal and visceral pleura, it may happen that inadvertently the general pleura is opened with collapse of the lung and infection of the general pleura. It has been my experience that by judicious waiting the interlobar pus collection will increase in size, and when it has come safely near the surface, adhesions will form between the visceral and parietal pleura and the abscess can be opened with perfect safety. It is preferable to operate an interlobar empyema through a costatectomy, as it is important to expose a large surface of the lung, so as to visualize, if possible, the interlobar fissure. The adhesions should then be separated and the abscess drained. Occasionally this cannot be done and the abscess must be evacuated through the parenchyma of the lung. Whenever possible this should be avoided, as it prevents the prompt treatment with Dakin's solution and may give rise to pleuropulmonary fistulæ.

BILATERAL EMPYEMA.

Until recently bilateral empyemata have been looked upon as particularly dangerous. It is true that the mortality of these is higher than that of unilateral empyemata, but the reason for the high mortality is not the empyema but the bilaterality of the pneumonia. When the pneumonias have run their course and the case has reached the acute stage of the end-product, empyema, with well walled-off adhesions, neither the condition nor the operation is dangerous. While I would not hesitate, if urgency demanded it, to operate both sides simultaneously (and I have done so) it is preferable to do so at different sittings.

COMPLICATIONS.

Complications of unoperated empyemata are rare. Indeed, it is hardly conceivable that an empyema may have complications except metastatic suppurations. I have seen quite a number of metastatic suppurations, especially in the joints, but, inasmuch as positive blood cultures in empyema are exceedingly rare, I have arrived at the conclusion that such suppurations are rather to be regarded as complications of the malady that gave the empyema than of the empyema itself. I wish to speak especially of one metastatic infection because of its pathogenetic significance. A brain abscess following an empyema is not conceivable on pathological physiological grounds, because there is no way for a thrombus to reach the brain from the pleura. Even, therefore, on purely hypothetical grounds we must assume that if a brain abscess occurs as a complication of empyema there must also be an abscess of the lung, because it is only from such a source that an infective thrombus in the brain may arise.

The complications of a badly treated empyema are legion. The most important is sepsis due to inefficient drainage.

I have already alluded to one of the complications arising from too early operation, namely, the occurrence of enormous cavities. Indeed, I believe that these early operations are more responsible than any other factor for the invention of the multitude of secondary operations.

MORTALITY.

Permit me to quote first a few statistical figures, which a hasty review of the literature, gathered at random, revealed:

Lavrow[5] figures a mortality of 55 per cent. for all cases, in adults alone 45 per cent. Dunlop[6] reports a mortality of 36 per cent. in the empyemata in children. Lloyd[7] reports a very low mortality, namely, that of 20 per cent. Various German clinics quoted by Hahn[8] report a mortality varying between 8 and 25 per cent. Holt[9] gives for children under one year a mortality of 73 per cent. and for those under two years a mortality of 58 per cent. Dowd,[10] in a study of 285 cases, 238 of which were children between the age of two and fourteen years, reports a mortality of 25.6 per cent. Lilienthal[11] reports the statistics of 95 cases which were operated upon his service at Mt. Sinai Hospital between 1914 and 1917, and shows that he reduced the mortality to 18.9 per cent.

In 299 consecutive cases, collected by Wilensky,[12] from the records of Mt. Sinai Hospital, which occurred between 1904 and 1914, there was a mortality of 28 per cent. In extenuation of this high mortality it is but proper to mention that a large number of these were in infants and that many were in a very poor general

condition, frequently not surviving the simplest operation. (Insertion of a catheter through a trocar.)

Let me furthermore quote from a "report on empyema" which has been rendered to the Surgeon-General of the Army by Major Evarts A. Graham and which he has compiled from the replies to a questionnaire transmitted from the principal Base and General Hospitals.

"The average mortality based on the replies from 25 camps, which gave their results is 30.2 per cent. But this mortality, as high as it is, does not begin to represent the remarkably high mortality which has occurred in some of those camps which had a large number of cases. For example, at Camp Funston, in 85 cases of empyema the mortality has been as high as 84 per cent. Again at Camp Greene, in 92 cases of empyema, it has been 53.2 per cent.; at Doniphan it has been 57 per cent. and at Wheeler, 65 per cent."

Continuing further Graham says: "Possible explanations of the striking differences in mortality reported from various camps in the empyema cases are to be found: (1) In the fact that there has been a marked disagreement concerning what cases should be considered as empyema, and (2) in the method of treatment employed.

"Owing to the fact that the exudate most commonly found is a slightly turbid serofibrinous fluid, with pus demonstrable only microscopically, in some of the camps only those cases have been considered as empyema which yielded frank macroscopic pus. In general, those camps which reported the lowest mortality have regarded as cases of empyema only those in which the exudate has been frank pus; and conversely the highest mortality figures have come from those camps in which all cases showing even microscopic pus in the pleural exudates have been considered as cases of empyema."

I have quoted above the mortality statistics taken at random from a number of observers. On the other hand, conversations upon the subject with colleagues in various parts of the country almost universally elicited the reply that their mortality in empyema was very low. When asked to study their figures they confessed to a mortality of respectable dimensions. I have gained the impression that the mortality percentage gained from actual statistics is high while the mortality percentages quoted from memory is low.

In spite of the very high mortality quoted I have arrived at the conclusion that empyema as such has a very low mortality. I would even go so far as to say that empyema should have no mortality. When a patient dies with an empyema in the acute stage the cause of death is not the empyema but the pneumonia which caused it. A striking evidence of this is seen in cases of undiagnos-

ticated empyema; at autopsy there is always found a pneumonia in the fullest bloom. If the late operation is done, *i. e.*, when the pneumonia has run its course, the operation is perfectly simple and even patients in a greatly debilitated condition stand it with ease and safety.

That a badly treated empyema has a mortality goes without saying, but mortality percentages presume proper treatment. If such a patient dies, the cause of death should not be ascribed to the empyema but to the bad treatment.

III. Treatment of Chronic Empyema.

In view of the experiences which I have gained, particularly during the last two years, I have a certain diffidence in defining the word "chronic," as it bears upon a case of empyema. Formerly a case of empyema was considered chronic, which did not heal or which lasted a long time, and which usually required at least one secondary operation for healing. I do not consider this definition a very happy one for reasons which will become apparent.

My conception regarding the manner in which an empyema heals has undergone a very radical change since my recent experience. Formerly I was under the impression that an empyema healed in only one way, namely, by a process of obliteration, which in turn was caused by a gradual expansion of the lung, and by the formation of adhesions between the visceral and parietal pleura. Only when the entire affected pleural surfaces became adherent did the drainage opening close. This is the only method of healing that was known up to two or three years ago and may for that reason be called the "classical method." It has been stated that a properly drained empyema, even without the use of any antiseptics, sterilizes itself, but I have never found this to be the case; on the contrary I found numerous bacteria up to the very moment of final closure. When the cavity persisted I observed that the drainage opening did not show the slightest tendency to close; on the contrary, in spite of earnest prayers, and perhaps extensive operations, it failed to close in many instances.

During the past three years the following variations in the method of healing of an empyema have been scientifically established:

1. The far-reaching observations at the War Demonstration Hospital of the Rockefeller Institute have taught us that empyema cavities can be rendered bacteriologically sterile by means of the Carrel-Dakin treatment, and when sterile the drainage opening can be closed by secondary suture. According to the reports from the Rockefeller Institute a definite cure results in about 75 per cent. of the cases. Personally I believe that recurrence follows in a certain percentage of these cured cases; but there is no denying

that a real cure follows in some cases. I am not aware that the method of healing has as yet been described in detail by the originators of the method. My own observations in a few cases have led me to the conclusion that the cavity heals by the absorption of the sterile exudate that fills the cavity after closure of the wound.

2. During my stay at General Hospital No. 12 I had an experience which threw a flood of light upon my speculations as to the closure of empyemata. An empyema treated by the Carrel-Dakin method had been finally allowed to heal. About one month after healing my colleague upon the Empyema Commission, Dr. Franklin A. Stevens, found upon routine physical examination, which was verified subsequently by roentgen-ray examination that the patient had a definite pneumothorax. I watched this case with great interest and care. An occurrence of this character was unknown to me, and I confidently looked forward to a reaccumulation of the pus. The unexpected, however, happened. Not only did no reaccumulation occur, but the pneumothorax disappeared and was replaced by the expanding lung.

3. The occurrence in the case just related made me think very hard. It gave me the clue that I needed. Whereas up to that time operations upon cases of chronic empyema were of almost daily occurrence with me, I immediately ceased all further operating, and merely proceeded with the intensive sterilization of the cavity. When sterilization was complete all treatment was discontinued and the outer wound was allowed to close. Subsequent examinations showed that the healing occurred through the intermediary stage of a pneumothorax, as in the case just related.

There are therefore in addition to the "classical" method at least two other methods of healing of empyema. It is on this account that I now find difficulty in defining the word "chronic" as it relates to empyema; but in the light of our present knowledge I would exclude from the chronic group any case of empyema which is amenable to sterilization by means of the Carrel-Dakin treatment.

If the cases of empyema which cannot be remedied by even long-continued treatment with Dakin's solution are examined there will always be found a definite underlying cause the removal or eradication of which, occasionally by a very trivial operation, will lead to successful issue. These reasons are not very numerous, viz.:

1. *Cases in Which Drainage Opening is not Dependent.* In the commonest form of empyema, namely, that located in the postero-inferior part of the thorax, almost any opening into the chest situated posterior to the midaxillary line is dependent as long as the patient is in a recumbent posture. If, however, the drainage opening has been placed too high, trouble promptly ensues, when the patient assumes the erect posture, because a chance is given for the formation of an undrained or poorly drained part below

the drainage opening. The establishment of a second drainage opening in the dependent position will promptly remedy the error.

2. *Cases with Contracted Drainage Opening.* It is surprising how many cases of empyema are allowed to drift into a state of chronicity on account of the neglect of this very obvious fault. They formed a very large percentage of the cases in the military service. In the treatment as advocated by me for all cases of empyema an adequate opening is a most important element, not only for the purpose of drainage but also to permit a proper sterilization of the cavity. The drainage opening should permit the easy introduction of at least one good-sized drainage tube, and, depending upon the size of the cavity, from two to six Carrel tubes. The treatment of cases of chronic empyema due to a contracted drainage opening depends upon whether or not this opening can be dilated sufficiently by the introduction of increasingly larger and larger drainage tubes. If this is possible that is all that is necessary; if it is impossible, because of the reformation of the previously resected rib, it is advisable to again excise the rib.

3. *Cases with Necrotic Ribs.* This is a very frequent cause for our inability to sterilize the empyema cavity. The researches of Blake have definitely proved that the interstices and the Haversian canals of sequestra teem with bacteria, and in consequence the Dakin solution never reaches these bacteria. The result is that the empyemic cavity is becoming continuously reinfected. The treatment is self-evident, namely, removal of the sequestra or necrotic ends of the ribs.

4. *Cases with Retained Foreign Bodies.* These form a large percentage (13 per cent.) of the cases that cannot be sterilized by the Carrel-Dakin treatment. The variety of foreign bodies which has been lost in an empyema cavity is unlimited. The most frequent is drainage tubes, including Carrel tubes. Other foreign bodies that I have found were gauze sponges, tampons, rubber dam, large loose sequestra, etc. The diagnosis of rubber tubes should be readily made with the roentgen rays; yet it is surprising that even they may be overlooked.

5. *Cases with Side Pockets and Lateral Branch Sinuses.* The formation of these is a rather interesting problem and may occur in one of several ways. Usually the adhesions in empyema form in a more or less regular line around the periphery of the exudate; sometimes, however, the adhesions form in an irregular manner, so that lateral pockets form which drain through a small opening into the main cavity; after a while these pockets contract, forming tortuous lateral sinuses.

Occasionally it happens that the adhesions form in such a peculiar manner that we are dealing from the very outset with two separate empyemic cavities, separated by a wall of adhesions. In a majority of cases the adhesions are so firm that the two cavities

remain separate for an indefinite time. In some instances the smaller cavity ruptures into the main cavity and makes a communication which is usually inadequate for drainage and treatment.

Finally, irregular cicatricial contractions may occur in the wall of a sinus, which has drained for a long time, thereby shutting off a portion of the sinus, forming a sort of irregular figure of 8.

The reason why these cavities do not heal is simple; they are impossible of sterilization by the Carrel-Dakin method. In their treatment an accurate diagnosis of their location and extent is of prime importance; this can be very readily done by means of the roentgen ray after injecting an opaque substance. Such side pockets should be opened (usually by costatectomy) and sterilized independently of the main cavity. When this is impossible, their exposure through a large intercostal incision by way of the main cavity is indicated.

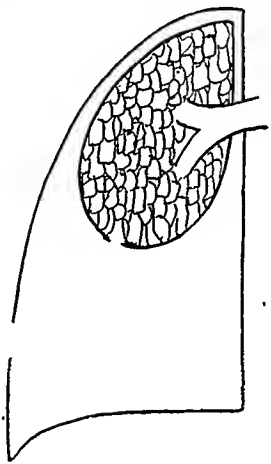

FIG. 10.—Pleuropulmonary fistula.

6. *Pulmonary Fistulæ.* The etiology of these has already been discussed in detail in the chapter on pathogenesis. When the abscess causing the empyema is small, the perforation usually closes early, so that the injection of Dakin's solution may be carried out without causing disagreeable by-effects.

If there is a communication of the abscess with a bronchus of larger size, we obtain the not infrequent complication known as "pleuropulmonary fistula" (Fig. 10). In the presence of this lesion distention of the cavity with large quantities of Dakin's solution

causes a very distressing cough. Such patients, however, stand the instillations of smaller amounts with perfect comfort, more particularly if attention is paid to the posture of the patient, while the fluid is instilled. A position will nearly always be found in which the instillations do not cause distress. In rare instances the fistula is of unusual size, varying in diameter from that of a pencil to a little finger.

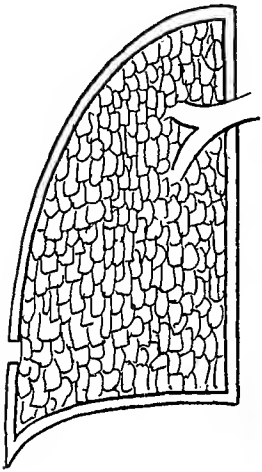

FIG. 11.—Bronchocutaneous fistula.

FIG. 12.—Residual empyema.

Finally it may happen in some cases of empyema, particularly those that have drained for a long time, that the lung has expanded until it fills the entire pleural cavity. In such instances the opening into the lung may become adherent to the drainage opening. There is formed a short channel, leading directly from the skin into a bronchus. On coughing air a slight amount of bronchial mucus is expressed. A sinus of this description should be called "bronchocutaneous fistula." They are exceedingly difficult, if not impossible, to cure without operation, because the bronchial and cutaneous epithelium become continuous and form a so-called "lip fistula." In rare instances I have succeeded in curing these fistulæ by a thorough cauterization of the tract with a fine Paquelin cautery. Formerly I have practised extensive operations upon these cases, the operation consisting in an extensive thoracoplasty followed by extirpation and suture of the sinus. I believe, however, that in

most instances this is not necessary. Satisfactory results are obtained by mobilizing the lung and excising the sinus. Thereby converting the bronchocutaneous fistula into a pleuropulmonary fistula. Subsequent healing is not, as a rule, protracted; an inversion suture of the fistulous opening in the lung may shorten the period of healing.

RECURRENCES.

The question of recurrences is intimately connected with that of chronic empyema; in fact, a chronic empyema may well be defined as one which has a tendency to recur.

If we analyze the physical forces which enter into the healing of an empyema we will find that they are composed of several factors, all of which tend to diminish the thoracic cavity. They are: (1) The ascent of the diaphragm, (2) the direction of the ribs becomes more vertical, (3) the intercostal spaces become narrower, and (4) the arc of the ribs approaches closer to the median line. At the same time the lung expands until the parietal and visceral pleura become adherent. It is only when this stage has been reached that we can speak with any degree of certainty about a cure; whenever a space is left there is always the possibility of a recurrence. Broadly speaking, therefore, these reaccumulations are always a reflection upon the method of treatment, for usually they mean that drainage and antiseptic treatment of the cavity have been discontinued prematurely. I have found that this contingency is particularly liable to occur if the external incision is closed operatively, because it not infrequently happens that good judgment is supplanted by haste. Even the strictest precautions, such as smears and bacteriological cultures, do not always furnish a reliable guide to the presence or absence of microörganisms. It again only proves the value of the well-recognized axiom in medicine, that a negative proof is no proof.

An excellent resumé of the recurrences in empyema has been compiled by Dr. Franklin A. Stevens.[13] Stevens shows that recurrences are less frequent after the Carrel-Dakin treatment, as proved by the following figures.

1. Healed without Carrel-Dakin treatment		56	
Recurrences	10 =	18	per cent.
2. Healed with Carrel-Dakin treatment		63	
Recurrences	3 =	4.7	per cent.

The diagnosis of recurrent empyemata is difficult if the signs and symptoms are not marked. Examinations with the roentgen ray, especially stereoscopically[1] are of prime help.

The treatment of recurrent empyema differs in nowise from that of an ordinary empyema. Owing to a narrowing of the intercostal spaces it is usually preferable in recurrent cases to resect a rib.

RESIDUAL EMPYEMATA.

Many observers group residual empyemata with the recurrent empyemata; this is erroneous, because of essential differences in their pathogenesis.

Residual empyema is the result of an irregular and multilocular encapsulation during the formative stage of the empyema. At the primary operation, as a rule, the smaller of the two cavities is overlooked, so that only the larger is drained. Sooner or later the patient does not do as well as he should, and upon physical examination, sometimes even long after the main cavity is healed, another pus focus is found.

The diagnosis of the existence and location of these residual empyemata is exceedingly difficult, particularly if they are of small size. There are two symptoms which should lead one to suspect a residual empyema: (1) A recurrent or daily evening fever, and (2) perhaps even a more important symptom, the fact that the patients do not regain their normal weight no matter how liberally fed.

It is the fear of these residual abscesses which lead some surgeons to advocate a wide operation for all primary empyemata, exploring the entire chest, and breaking up all adhesions and septa. I cannot concur in this opinion, as I deem it preferable to do two comparatively trivial and safe operations to one large and hazardous one. Furthermore, the occurrence of residual empyema is too rare to justify such extensive and formidable primary operations.

Occasionally the second pus focus breaks through into the primary cavity; usually a second operation is necessary. If a residual empyema has not been discovered until sometime after the primary operation a costatectomy is indicated, because of the narrowing of the intercostal spaces. In the cases in which the existence of the second pus focus is known at the primary operation, and in these the term of "multilocular empyema" is more applicable, an intercostal incision is all that is necessary.

CHRONIC EMPYEMA SINUS.

Custom makes a very definite distinction between these and the previously discussed cases of chronic empyema. There is in reality no difference, as it is merely a question of degree. Some cases of chronic empyema have a large cavity and a short sinus; others have a long sinus and a small cavity. Special operative procedures in large numbers have been described for their cure, most of which, to my mind, without any particular justification. I believe what I have said of the treatment of chronic empyema in general applies to that of the chronic sinus as well.

OPERATIVE PROCEDURES IN CHRONIC EMPYEMA.

In spite of the best of care some cases of empyema will not heal. I have no hesitancy in stating, however, that if the treatment of the acute and chronic stage is carried out along the lines laid down in previous portions of my paper their number will be infinitesimal as compared to former years. It is in these cases, and in these cases only, that recourse must be had to one of the major operations so called.

The major operations (and I use the word major deliberately, because not one of the originators of the method will confess to really "major" character of his operation) can be divided into two main groups:

I. *The operations which aim to obliterate the empyemic cavity by collapsing the chest wall.* (Estlander, Schede, Quenu, Beck.)

1. Estlander's[14] operation aims at an extirpation of that part of the bony chest wall which overlies the empyemic cavity. The soft parts of the chest wall are then packed down into the cavity against the visceral pleura. The method is applicable only in cavities of limited extent.

2. The Schede[15] operation is decidedly more extensive, but is applicable in cases of total empyema. It follows, therefore, that in comparison with the preceding the Schede operation is one of magnitude and should by no means be lightly undertaken.

3. The Quenu operation is only a modification of the Estlander operation, which it is supposed to supplant. In this operation the ribs overlying the cavity are not removed but are divided at two ends of the incision, so that instead of having a flap made up only of soft tissues the flap is made up of soft tissues plus mobilized ribs. The entire flap is then depressed so that it comes into contact with the visceral pleura.

4. Beck[16] reports very satisfactory results from his "flap-sliding operation." I cannot, however, even after a careful reading of his publication, see wherein this operation differs materially from the Estlander unless it is in the cutaneous incision; and all writers after Estlander, and even Estlander himself, have already deviated from his original incision; in fact, it is recommended that this be done.

II. *The operations which aim at a reëxpansion of the lung by liberating it from the heavy, more or less organized, fibrous deposit, which confines the lung, and prevents its expansion.* (Delorme, Fowler, Lilienthal, Ransohoff.)

1. The Delorme[17]-Fowler[18] operation aims at a reëxpansion of the lung by removing the fibrous deposit which covers and confines the lung. Unfortunately the operation does not always succeed: (1) Because the peeling away is exceedingly difficult, if not impossible, so that numerous perforations are made into the parenchyma of

the lung; and (2) because in cases of long duration the lung itself is already fibrosed to such an extent that it no longer expands.

2. The Lilienthal[19 20] operation aims at a similar objective. This operation is a decided improvement upon the former, because it is not near as formidable. Lilienthal has conclusively demonstrated that with the aid of a good rib spreader the entire operation can be done through a long intercostal incision, with the possible added rapid temporary division of one or two ribs near their angle.

3. Ransohoff[21] attempts to overcome the not infrequently found difficulty of not being able to peel back the fibrous deposit by merely making innumerable incisions into it in criss-cross fashion.

It is exceedingly difficult to give an absolute indication as to the choice between these operations. Personally I am of the opinion that all of them have a very definite, though in the light of my present knowledge, a much more limited indication than was formerly thought to be the case. At the present moment I am more inclined to favor the lung expanding operations over the chest collapsing operations: (1) Because they are much more conservative of lung function, and (2) because they are followed by less deformity. In a certain number of cases good results will be obtained from the combination of the two methods.

All these operations have a very definite mortality. The Estlander operation has the lowest mortality (about 15 per cent.), but the real indications for this operation are limited. The Schede operation has the highest primary mortality (over 20 per cent.). The definite cures in all vary between 50 and 60 per cent. The remainder makes up the deaths, improvements and failures.

In my military service, before I found that I could heal chronic empyemata by simpler methods, I performed a number of Schede and Estlander as well as Delorme operations; all of my patients were in such excellent physical condition by the time they came to operation, with absolutely sterile cavities, that I did not have a single fatal issue. In passing I may mention that I have found the decortication operation particularly difficult in the empyemata caused by the hemolytic streptococcus. Of late, again, more frequent recourse is had to the decortication operation in the military service and, I am given to understand, with very gratifying results.

As is seen I place the indications for these operations quite differently than I did in my previous communications[22] upon the subject. Formerly I was much more radical in my views and I recommended extensive operations in cases which I know now would heal without any operation.

BISMUTH PASTE TREATMENT OF EMPYEMA.

The treatment of chronic empyemata with the injection of Beck's bismuth paste is deserving of special consideration. The

method comes very highly recommended not only from its originator but also from other surgeons. I also have used it and was particularly careful to follow all instructions; regrettably, however, my results were not very encouraging. In a few instances, it is true, healing followed very promptly, but the cure was only of limited duration, because practically all of the cases were followed by a recurrence, extrusion of the bismuth paste and continuance of the suppuration. An additional and important drawback of the method is that, in spite of all precautions to obtain pure chemicals, it is occasionally followed by toxic symptoms; a number of these cases were encountered in the military service. Beck advises the injection of warm olive oil for the removal of the bismuth paste, but I have not found this to be very efficacious, more particularly when the channel or cavity is very tortuous.

CONCLUSIONS.

1. Empyema in most instances results from the rupture of a small subpleural pulmonary abscess.

2. An empyema is the final stage of a process in which the first stage is a serous pleurisy and the second a seropurulent pleurisy. The latter is the so-called "formative" stage of an empyema.

3. The "formative" stage is unaccompanied by pleural adhesions. The stage of final empyema is always accompanied by adhesions.

4. The vast majority of empyemata are of the encapsulated variety. Very few occupy the entire pleural space.

5. Metastatic suppurations accompanying empyema are to be found rather as complications of the causative pneumonia than of the empyema.

6. The treatment of an empyema should be begun in the formative stage before the exudate has been converted into frank pus.

7. It is unwise to perform an operation in the formative stage. The mortality is terrific because the accompanying pneumonia is still in full bloom, and, furthermore, because of the absence of adhesions there occurs a pneumothorax with "fluttering of the mediastinum" and consequent embarrassment of the heart action.

8. The best surgical procedure in the formative stage is repeated aspirations, done every twelve to twenty-four hours, in order to relieve the respiratory embarrassment due to the mechanical pressure of the rapidly accumulating fluid. In a few cases this measure is curative.

9. Feeding with a diet rich in calories is an important adjuvant in the treatment of the formative stage.

10. The treatment in the acute stage of an empyema consists in a simple intercostal thoracotomy. This operation need not be considered an urgent one, and should be performed when the

patient's condition is otherwise perfectly satisfactory. This is the so-called "late" operation.

11. Urgent thoracotomy is indicated only in acute pyopneumothorax.

12. The Carrel-Dakin treatment, properly carried out, has proved of superlative value in the postoperative treatment of empyema and should be used in every case. There are no contraindications to its use.

13. The mortality of acute empyema by these methods is lower than that reported by other methods of treatment.

14. Empyema cavities heal by three methods: (*a*) By the formation and absorption of a sterile exudate; (*b*) by the formation and "absorption" of a closed pneumothorax; (*c*) by the "classical" method, *i. e.*, the expansion of the lung and obliteration of the pleural cavity by adhesions.

15. Chronic empyema should not occur, or at least should become very rare, if the methods of treatment of acute empyema as formulated above are practised.

16. "Chronic" cases of empyema may be defined as such which are not amenable to treatment by the Carrel-Dakin method.

17. Recurrences in empyema are usually the result of undue haste. The percentages of recurrences is less after the Carrel-Dakin method of treatment than after any other.

18. The vast majority of operations that have been devised for chronic empyema will have a very limited field of usefulness if the methods of treatment advocated above are carried out.

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